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(54) Title: OPTICAL FIBER PRODUCING METHOD

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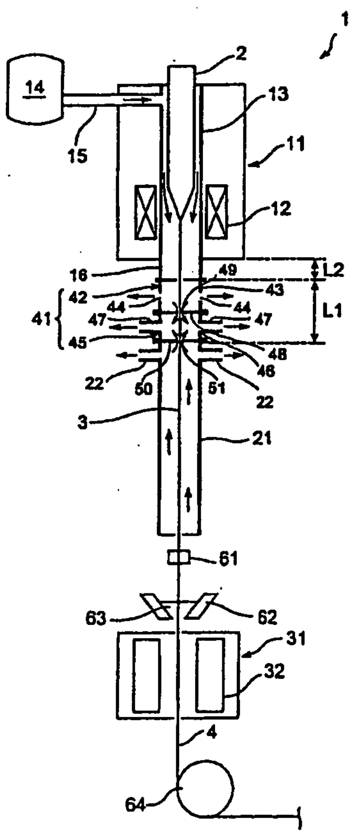

(57) Abstract: A drawing device (1) has a drawing furnace (11), a protective tube (21) and a resin curing section (31). Disposed between the drawing furnace (11) and the protective tube (21) is a buffer chamber (41), having a length (L1) as seen in the drawing direction of optical fibers (3). The buffer chamber (41) is composed of a first buffer chamber (42) and a second buffer chamber (45). The inner space of the buffer chamber (41) contains a mixture of He gas which is the atmosphere gas in the drawing furnace (11) and air which is the atmosphere gas in the protective tube (21). The optical fibers (3) heated and drawn in the drawing furnace (11) are fed into the protective tube (21) and their predetermined regions are slowly cooled at a predetermined cooling rate. Thereafter, a UV resin liquid (63) is applied to the optical fibers (3) by a coating die (62), the UV resin (63) being cured in the resin curing section (31); the optical fibers become an optical fiber strand (4).

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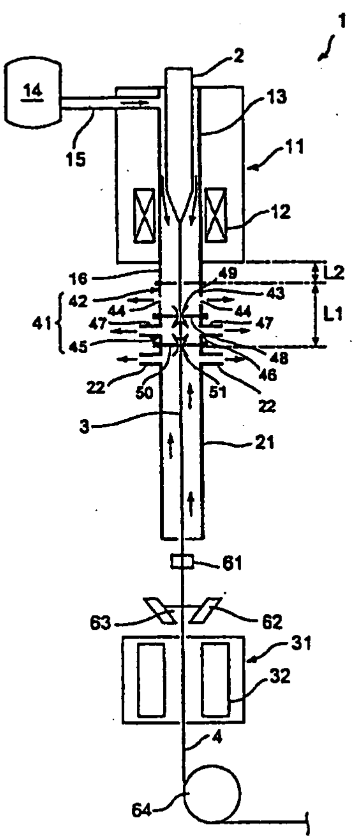


(57) Abstract: A drawing device (1) has a drawing furnace (11), a protective tube (21) and a resin curing section (31). Disposed between the drawing furnace (11) and the protective tube (21) is a buffer chamber (41), having a length (L1) as seen in the drawing direction of optical fibers (3). The buffer chamber (41) is composed of a first buffer chamber (42) and a second buffer chamber (45). The inner space of the buffer chamber (41) contains a mixture of He gas which is the atmosphere gas in the drawing furnace (11) and air which is the atmosphere gas in the protective tube (21). The optical fibers (3) heated and drawn in the drawing furnace (11) are fed into the protective tube (21) and their predetermined regions are slowly cooled at a predetermined cooling rate. Thereafter, a UV resin liquid (63) is applied to the optical fibers (3) by a coating die (62), the UV resin (63) being cured in the resin curing section (31); the optical fibers become an optical fiber strand (4).

(57) Summary:

The line drawing equipment 1 possesses the line drawing furnace 11, the protective tube 21 and the resin hardening portion 31. Between the line drawing furnace 11 and the protective tube 21, the buffer chamber 41 is provided; the length in the line drawing direction of the optical fiber 3 of this buffer chamber 41 is set to be L1. The buffer chamber 41 is constructed of the No. 1 buffer chamber 42 and the No. 2 buffer chamber 45. The space inside the buffer chamber 41 contains a mixture of He gas which is the atmospheric gas inside the line drawing furnace 11 and air which is the atmospheric gas inside the protective tube 21. The optical fiber 3 which has been heat-line drawn line in the line drawing furnace 11 is delivered to the protective tube 21; and the specified location of the optical fiber 3 is gradually cooled at a specified cooling speed. After this, to the optical fiber 3, by the coating die 62, the UV resin liquid 63 is applied and the UV resin 63 is hardened at the resin hardening portion 31 to become the optical fiber base line 4.

DETAILED DESCRIPTION

MANUFACTURING METHOD OF OPTICAL FIBER

Technical Field

The present invention is related to a manufacturing method of optical fiber in that by reducing the Rayleigh scattering intensity, the transmission loss is made lower.

Technology Background

From the demands of reducing the cost of optical fiber, etc., the line drawing technique of line drawing optical fiber from a large diameter (for example, 70 mm in diameter) optical fiber preform is becoming commonly applied. In the case of line drawing fiber from a fat diameter optical fiber preform, the space of the neck-down circumference would become larger and the temperature distribution of the gas flowing this space would become heterogeneous. Because of this, disturbance to the gas flow in the space of the neck-down circumference would occur so that the fluctuation of the optical fiber diameter would become larger. For controlling the fluctuation of the optical fiber diameter, as an atmospheric gas inside the line drawing furnace, He gas having a high thermal conductivity is used in some cases.

And, for preventing the fluctuation of the optical fiber diameter by the flow disturbance of the outside air at the downward of line drawing furnace, a technique in that a furnace core tube extension portion (also called as the bottom chimney) is provided to the line drawing furnace to isolate the optical fiber immediately after the line drawing from the outside air is known.

Revelation of the Invention

The task of the present invention is to provide a manufacturing method of optical fiber which can manufacture an optical fiber in that by the reduction of Rayleigh scattering intensity, the transmission loss is made lower even in the case where He gas possessing a high thermal conductivity is used as the atmospheric gas inside the line drawing furnace.

The present inventors carried out penetrating research on the manufacturing method of optical fiber in that the transmission loss is lowered by the reduction of the Rayleigh scattering intensity. As a result, relative to the relationship between the Rayleigh scattering intensity and the cooling speed of optical fiber after the line drawing, the new fact below was discovered.

The atoms in the glass of high temperature are vibrating severely by the heat energy; compared to the glass of low temperature, the atomic arrangements are in disorder condition. When a high temperature glass is gradually cooled, in the temperature range where the rearrangement of atoms are allowable, the atoms would arrange in the level of disorder corresponding to each temperature while being cooled; thus the degree of the disorder of the atoms inside the glass would become the state corresponding to the lowest temperature (1200°C level) where the structural relaxation would progress. However, if the high temperature glass is rapidly cooled, the atomic arrangement would be cooled-fixed before it reaches the equilibrium state corresponding to each temperature. Because of this, the atomic arrangement would become disordered compared to the case where it is cooled gradually. The Rayleigh scattering intensity would become larger when the atomic arrangement is greater in disorder even in the

identical material. In the optical fiber cooled at the cooling speed of 5000—30000°C/second level after the line drawing would become more disordered in atomic arrangement compared to the bulk glass; it would become the state of high fictitious temperature. It is thought that this would become the cause that, in general, the Rayleigh scattering intensity would become larger in optical fiber.

Now, the time required for structural relaxation would become longer as the temperature becomes lower; for instance, at 1200°C level, the structural relaxation would not occur until it is maintained at this temperature for several tens of hours. The optical fiber after the line drawing is generally cooled from 2000°C to about 400°C in several seconds. During the short time when the optical fiber is cooled in the line drawing process, for lowering the fictitious temperature to make this fictitious temperature to approach 1200°C, it would be necessary to gradually cool the optical fiber after the line drawing at a temperature condition higher than 1200°C.

Accordingly, the present inventors paid attention to the optical fiber temperature and the cooling speed after the line drawing and investigated the relationship between the cooling speed and the Rayleigh scattering coefficient for the portion from 1200 to 1700°C (namely, the portion higher than the lowest temperature (about 1200°C) where the above described structural relaxation would proceed and lower than1700°C where the structural relaxation would proceed in an extremely short time). As a result, it was verified that the relationship shown in Fig 7 is present between the cooling speed and the Rayleigh scattering coefficient in the portion of the temperature from 1200 to 1700°C for a pure quartz core fiber. Further, the Rayleigh scattering intensity (I) possesses the property that

it is inversely proportional to the 4th power of wavelength (λ) as shown in equation (1) below. In this, the coefficient A is assumed to be the Rayleigh scattering coefficient.

$$I = A / \lambda^4 \quad \cdots\cdots\cdots\cdots\cdots \quad (1)$$

From this result, it was be able to verify that by slowing the cooling speed at a specified section of the portion where the optical fiber temperature is in the range from 1200 to 1700°C to reduce the Rayleigh scattering intensity, the transmission loss can be made lower.

And, the present inventors also made new discovery on the relationship between the length of the bottom chimney and the transmission loss. In the case where the bottom chimney is set to be relatively longer, since the optical fiber would be rapidly cooled by the high thermal conductivity He gas inside the bottom chimney, the Rayleigh scattering of the optical fiber cannot be lowered; thus, the transmission loss would become higher.

In the case where the length of the bottom chimney is shortened to suppress the rapid cooling of the optical fiber in the bottom chimney by the He gas , the optical fiber coming out from the bottom of the chimney would be gradually cooled by the lower thermal conductivity outside atmosphere (air); because of this, the Rayleigh scattering intensity of the optical fiber would be reduced so that the transmission would become lower. However, in this case, since the optical fiber would be contacting the unstable outside atmosphere, there would be a problem that the fluctuation of the optical fiber diameter would become larger.

Now, as a manufacturing method and equipment of hermetically coated fiber, the present applicant filed the Patent Disclosure Bulletin No. 6-48780 (1994). In the technique described in this Patent Disclosure Bulletin No. 6-48780 (1994), in addition to

making the line drawing furnace inside to a He gas atmosphere, the raw material gas (hydrocarbon) is decomposed inside the reaction tube provided to the line drawing furnace bottom portion to perform hermetic coating to the optical fiber surface. A buffer chamber is provided between the line drawing furnace bottom portion and the reaction tube; and from this buffer chamber, He gas is discharged to the outside. However, in this Patent Disclosure Bulletin No. 6-48780 (1994), the new discovery, made by the present inventors, that by slowing the cooling speed at a specified section of the portion where the optical fiber temperature is in the range from 1200 to 1700°C, to lower the Rayleigh scattering intensity, the transmission loss can be made lower was not revealed or indicated.

Based on the research result, for achieving the aforementioned objective, the optical fiber manufacturing method of the present invention is characteristically as follows: It is a manufacturing method of optical fiber in that an optical fiber preform is heated-line drawn. In this, a line drawing furnace for heating-line drawing the optical fiber preform under an atmosphere composed of He gas and a protective tube which is arranged with a specified spacing against the line drawing furnace and the atmosphere inside the protective tube is composed of a specific gas possessing a thermal conductivity which is lower than that of He gas are used. The space between the line drawing furnace and the protective tube is set to be a gas mixture existing layer where He gas and specific gas are mixed. The line entering temperature of the line-drawn optical fiber into the gas mixture existing layer is set to be 1400—1800°C and meanwhile, the optical fiber line drawn from the line drawing furnace is delivered into the protective tube through the gas mixture existing layer.

In the manufacturing method of the optical fiber related to the present invention, the protective tube is provided with a specified spacing against the line drawing furnace and furthermore, the space between this protective tube and the line drawing furnace is set to be a gas mixture existing layer where the No.1 gas possessing a specific thermal conductivity and the No.2 gas possessing a specific thermal conductivity are mixed. Because of this, inside the line drawing furnace is maintained to an atmosphere composed of He gas. And in the protective tube, an atmosphere composed of specified gas is maintained; therefore, the cooling speed of the optical fiber inside the protective tube can be made slower. Especially, since the line entering temperature into the gas mixture existing layer is set to be in the range of 1400—1800°C, the cooling speed of a specific section among the portion where the optical fiber temperature is within 1200—1700°C would become slower. As a result, the fictitious temperature of the optical fiber would become lower and the degree of disorder of the atomic arrangement would be lowered; thus, in an extremely short time from the heating-drawing to the resin coating, the Rayleigh scattering intensity is reduced so that the manufacturing of optical fiber lowered in transmission can be achieved.

And, since the gas mixture existing layer is present between the protective tube and the line drawing furnace, the invasion of the dusts occurring inside the line drawing furnace into the protective tube can be suppressed. Furthermore, by the presence of the gas mixture existing layer, the influence of the outside air flow disturbance to the space between the line drawing furnace and the protective tube would become less; thus, the occurrence of the optical fiber diameter fluctuation or the degradation of the bending of the optical fiber can be suppressed.

And, characteristically, it can be arranged that a partition wall for dividing the gas mixture existing layer and the outside air is provided and to the partition wall, a gas exhaust portion for discharging at least the He gas is formed so that at least the He gas is discharged to the outside from the gas exhaust portion.

By providing the partition wall, the influence of the outside air flow disturbance would become even less; thus, the occurrence of the optical fiber diameter fluctuation or the degradation of the bending of the optical fiber can be further suppressed. And, by discharging at least He gas to the outside from the gas exhaust portion formed to the partition wall, the He gas atmosphere inside the line drawing furnace and the specified gas atmosphere inside the protective tube can be efficiently and securely changed.

And, it can be characteristically that a gas introduction portion for introducing the specified gas is formed to the partition wall, and the specified gas is introduced inside the partition wall from this gas introduction portion.

By introducing the specified gas into the partition wall inside from the gas introduction portion formed to the partition wall, the He gas would be actively discharged from the gas exhaust portion; thus, the invasion of the dusts occurring (generated) inside the line drawing furnace into the protective tube can be further suppressed.

Brief Explanation of Figures

Fig 1 is a rough illustration diagram showing the No. 1 implementation mode of the manufacturing method of the optical fiber related to the present invention.

Fig 2 is a rough illustration diagram showing the No. 2 implementation mode of the manufacturing method of the optical fiber related to the present invention.

Fig 3 is a rough illustration diagram showing the No. 3 implementation mode of the manufacturing method of the optical fiber related to the present invention.

Fig 4 is a table showing the implementation examples based on the manufacturing method of the optical fiber related to the present invention and comparison examples.

Fig 5 is a rough illustration diagram showing the manufacturing method of the optical fiber by a comparison example.

Fig 6 is a rough illustration diagram showing the manufacturing method of the optical fiber by a comparison example.

Fig 7 is a diagram showing the relationship between the cooling speed of the optical fiber preform (Translator's note: "optical fiber preform" is a misprint of "optical fiber" ?) and the Rayleigh scattering coefficient.

Best Mode for Implementing the Invention

Implementation modes of the present invention are illustrated based on figures. Further, for the identical elements identical symbols are assigned in the illustration of the figures and the repetition of the illustration is omitted.

(No. 1 Implementation Mode)

First of all, by referring to Fig 1, No. 1 Implementation Mode of the manufacturing method of the optical fiber based on the present invention and the line drawing equipment to be used in this method is illustrated.

The line drawing equipment 1 is a quartz system optical fiber line drawing equipment which possesses the line drawing furnace 11, the protective tube 21 and the resin hardening portion 31. The line drawing furnace 11, the protective tube 21 and the resin hardening portion 31 are arranged in the order of the line drawing furnace 11, the

protective tube 21 and the resin hardening portion 31 as viewed to the line drawing direction of the optical fiber preform 2 (in Fig 1, from top to bottom). The optical fiber preform 2 held by the preform supplying device (not shown in the figure) is supplied to the line drawing furnace 11; the bottom end of the optical fiber preform 2 is heat-softened at the heater 12 inside the line drawing furnace 11 to line draw the optical fiber 3. In the furnace core tuber 13 of the line drawing furnace 11, the He gas supply passage 15 is connected from the He gas supply portion 14; the furnace core tube 13 inside of the line drawing furnace 11 would become an atmosphere composed of He gas. In the furnace core tuber 13, the heated-line drawn optical fiber 3 would be cooled by He gas. After this, the optical fiber 3 would pass through the furnace core tube extension portion 16. The thermal conductivity λ of He gas (T = 300 K) is 150 mW/(m-K).

The protective tube 12 is arranged with the specified spacing L1 against the furnace core tube extension portion 16. To the end portion of the line drawing furnace 11 side of the protective tube 21, the plural number of exhaust tubes 22 for discharging the He gas flowing from the line drawing furnace 11 inside and the dusts generated inside the line drawing furnace 11. The protective tube 21 is opened to the outside air, and it is constructed so that the protective tube 21 inside would become an atmosphere composed of air. The thermal conductivity λ of air (T = 300 K) is 26 mW/(m-K) which is lower than the thermal conductivity of He gas. Furthermore, as the specified gas possessing a thermal conductivity lower than that of He gas, instead of air, N_2 or Ar, etc. gases which are relatively larger in molecular weight can be used. In the cases when N_2 or Ar, etc. are employed, it would be constructed so that the gas supply portion as the No. 2 gas supply source is connected to the protective tube 21 through the gas supply passage. And, it is

not necessary that the exhaust tube 22 has to be formed. Furthermore, the protective tube 21 is not the reaction tube described in Patent Disclosure Bulletin No. 6-48780 (1994) for performing hermetic coating; it is not constructed to supply the raw material gas of hydrocarbon, etc. to the protective tube 21. And, the arrow mark inside the protective tube 21 indicates the upward flow occurring by the warming of the protective tube 21 by the optical fiber 3.

In the protective tube 21, the optical fiber 3 is cooled by air. Therefore, the cooling in the protective tube 21 is that among the heated-drawn optical fiber 3 portion to become 1200—1700°C, the section where the temperature difference of the optical fiber 3 would become more than 50°C, for example, the portion where the temperature of the optical fiber 3 would become 1500—1700°C (the section where the temperature difference would become 200°C) is to be cooled by a speed (4000—6000°C/sec level) slower than the cooling speed of He gas (20000—30000°C/sec level).

The setup position of the protective tube 21 and the total length of the line drawing direction (in the figure, to bottom direction) of the optical fiber preform are to be set by considering the line drawing speed so that among the portion where the temperature of the above described optical fiber 3 would become 1200—1700°C, the section where the temperature difference of the optical fiber 3 would become more than 50°C would be positioned and cooled at the protective tube 21. Here, the reason for considering the line drawing speed is that if the line drawing speed becomes faster, the position where the optical fiber 3 would become the same temperature would be lowered to the downside.

The buffer chamber 41 is provided between the furnace core tube extension portion 16 and the protective tube 21. The length of the optical fiber line drawing direction of this buffer chamber 41 is set to be roughly L1 as shown in Fig 1. There is some spacing (for example, 1—1.5 cm) present between the furnace core tube extension portion 16 and the buffer chamber 41. The furnace core tube extension portion 16 and the buffer chamber 41 are not directly connected. Further, it is not necessary to provide the space between the furnace core tube extension portion 16 and the buffer chamber 41. It can be constructed to tightly join the furnace core tube extension portion 16 and the buffer chamber 41. The length of the space between the furnace core tube extension portion 16 and the buffer chamber 41 is suitable at the length level which can prevent the invasion of the outside air into the furnace core tube extension portion 16 and the buffer chamber 41.

The buffer chamber 41 is constructed by the No. 1 buffer chamber 42 and the No. 2 buffer chamber 45. In the inside space of the buffer chamber 41 (the No. 1 buffer chamber 42 and the No. 2 buffer chamber 45), the mixture of He gas, which is the atmosphere of the line drawing furnace 11 (inside the furnace core tube 13), and air, which is the atmosphere of the protective tube 21 inside, is present.

The No. 1 buffer chamber 42 possesses the partition wall 43 for dividing the inside space where the optical fiber would pass through and the outside air. To this partition wall 43, a plural number of exhaust holes 44 for discharging the He gas flowing from the line drawing furnace 11 inside and the dusts generated inside the line drawing furnace 11 are formed. The No. 2 buffer chamber 45 possesses the partition wall 46 for dividing the inside space where the optical fiber would pass through and the outside air.

To this partition wall 46, a plural number of exhaust holes 47 for discharging the He gas flowing from the line drawing furnace 11 inside and the dusts generated inside the line drawing furnace 11 are formed.

The No. 1 buffer chamber 42 and the No. 2 buffer chamber 45 are divided by the dividing wall 48. To the dividing wall 48, the optical fiber passing through hole 49 for the optical fiber 3 to pass through is formed. The inside diameter of the optical fiber passing through hole 49 is set to be about 4—5 mm. The optical fiber passing through hole 49 would suppress the invasion of the He gas from the No. 1 buffer chamber 42 to the No. 2 buffer chamber 45 and the dusts generated inside the line drawing furnace 11. And, the No. 2 buffer chamber 45 and the protective tube 21 are divided b the dividing wall 50. To the dividing wall 50, the optical fiber passing through hole 51 for the optical fiber 3 to pass through is formed. The optical fiber passing through hole 51 is set to be about 4—5 mm in inside diameter, similarly to the optical fiber passing through hole 49. The optical fiber passing through hole 51 would suppress the invasion of the He gas from the No. 2 buffer chamber 45 to the protective tube 21 and the invasion of the dusts generated inside the line drawing furnace 11. Further, it can be constructed that by supplying N_2 gas, etc. from the exhaust tube 47 or the exhaust tube 22, the He gas flowing from the line drawing furnace 11 and the dusts generated inside the line drawing furnace 11 can be actively discharged. In this, a plural number of the exhaust tubes 22, 47 are provided, to be used as supplying tube for N_2 gas, etc. and as discharging tube of the supplied N_2 gas, etc. and the He gas, etc. flowing from the line drawing furnace 11.

The optical fiber 3 coming out from the furnace core tube 16 would then enter the buffer chamber 41 (No. 1 buffer chamber 42 and No. 2 buffer chamber 45) and enter the

protective 21 under the condition of being suppressed from contacting the outside air by the buffer chamber 41 (No. 1 buffer chamber 42 and No. 2 buffer chamber 45) The line entering temperature of the optical fiber 3 into the buffer chamber 41 (No. 1 buffer chamber 42) is set to be within the range of 1400—1800°C so that among the portion where the temperature of the optical fiber 3 would become 1200—1700°C, the section where the temperature difference of the optical fiber 3 would become more than 50°C would be cooled inside the protective tube 21. Further, the line entering temperature of the optical fiber 3 into the buffer chamber 41 (No. 1 buffer chamber 42) is especially preferable to be set within the range of 1600—1800°C. By setting the line entering temperature within the range of 1600—1800°C, a cooling of slowed down speed from relatively high temperature condition can be performed; thus the Rayleigh scattering intensity can be further lowered to manufacture an optical fiber 3 which is further reduced in transmission loss. Moreover, in the case where it is to be specified by the line temperature of the optical fiber 3 entering the protective tube 21, it is desirable to set the line entering this protective tube 21 to the temperature range of 1500—1800°C.

The optical fiber 3 coming out of the protective tube 21 is measured for the outside diameter online by the outside diameter measurement instrument 61. The measured value is fed back to the driving motor (not shown in the figure) for rotation-driving the fiber drawing equipment to control the outside diameter to the constant value. After this, the optical fiber 3 is applied for the UV resin 63 by the coating die 62 and the UV resin 63 is hardened by the UV lamp 32 of the resin hardening portion 31 to become the optical fiber base line 4. And, the optical fiber base line 4 is wound by the drum via

the guide roller 64. Further, instead of the UV resin 63, it can be constructed to use a thermal hardening resin and the thermal hardening resin is hardened by a heating furnace.

(No. 2 Implementation Mode)

Next, by referring to Fig 2, No. 2 Implementation Mode of the manufacturing method of the optical fiber based on the present invention and the line drawing equipment to be used in this method is illustrated. The No. 2 Implementation Mode is different in the structure of the buffer chamber from that of the No. 1 Implementation Mode.

In the line drawing equipment 101, the buffer chamber 141 is provided between the furnace core tube extension portion 16 and the protective tube 21. The length of this buffer chamber 141 in the line drawing direction of the optical fiber 3 is set to be L3 as shown in Fig 2. In the inside space of the buffer chamber 141, the He gas which is the inside atmosphere of the line drawing furnace 11 (furnace core tube 13) and the air which is the atmospheric gas of the protective tube 21 inside are mixed. Further, it is not essential that the exhaust tube 22 has to be provided.

The buffer chamber 141 possesses the partition wall 142 for dividing the inside space where the optical fiber would pass through and the outside air. To this partition wall 142, the introduction tube 143 for introducing N_2 gas into the buffer chamber 141 is formed. N_2 gas is delivered from the N_2 gas supply portion 151 to the introduction tube 143 via the N_2 gas supply passage 152. To the partition wall 142, the exhaust tube 144 for discharging the He gas flowing from the line drawing furnace 11 inside and the dusts generated inside the line drawing furnace 11 is formed. The buffer chamber 141 and the protective tube 21 are divided by the dividing wall 145. To the dividing wall 145, the optical fiber passing through hole 146 for the optical fiber 3 to pass through is formed.

The inside diameter of the optical fiber passing through hole 146 is set to be about 4—5 mm. And, the specified gas to be introduced into the buffer chamber 141 is not limited to N_2; air can also be employed. The large portion of the gas introduced into the buffer chamber 141 would be discharged from the exhaust tube 144. Further, the introduction of N_2 gas is not to fill up the protective tube 21; it is introduced to prevent the flowing of He gas, etc. into the protective tube 21.

(No. 3 Implementation Mode)

Next, by referring to Fig 3, No. 3 Implementation Mode of the manufacturing method of the optical fiber based on the present invention and the line drawing equipment to be used in this method is illustrated. The No. 3 Implementation Mode is different in the structure of the buffer chamber from those of the No. 1 Implementation Mode and the No. 2 Implementation Mode.

In the line drawing equipment 201, the buffer chamber 241 is provided between the furnace core tube extension portion 16 and the protective tube 21. The length of the of this buffer chamber 241 in the optical fiber line drawing direction is set to be roughly L4 as shown in Fig 3

There is some spacing (for example, 1—1.5 cm) present between the furnace core tube extension portion 16 and the buffer chamber 241. The furnace core tube extension portion 16 and the buffer chamber 241 are not directly connected. Further, it is not necessary to provide the space between the furnace core tube extension portion 16 and the buffer chamber 241. It can be constructed to tightly join the furnace core tube extension portion 16 and the buffer chamber 241. The length of the space between the furnace core tube extension portion 16 and the buffer chamber 241 is suitable at the

length level which can prevent the invasion of the outside air into the furnace core tube extension portion 16 and the buffer chamber 241. The He gas flowing from the line drawing furnace 11 inside and the dusts generated inside the line drawing furnace 11 are mostly discharged from the space between the furnace core tube extension portion 16 and the buffer chamber 241.

The buffer chamber 241 is constructed by the No. 1 buffer chamber 242 and the No. 2 buffer chamber 245. In the inside space of the No. 1 buffer chamber 242, principally, the mixture of He gas which is the atmosphere of the line drawing furnace 11 (the furnace core tube 13) and the air or N_2 supplied to the No. 2 buffer chamber 245 is present. And, in the inside space of the No. 1 buffer chamber 242, air which is the atmosphere of the protective tube 21 inside is present in some cases.. In the inside space of the No. 2 buffer chamber 245, principally, the mixture of air or N_2 being supplied and air (which is the atmospheric gas inside the protective tube 21) is present.

The No. 1 buffer chamber 242 possesses the partition wall 243 for dividing the inside space where the optical fiber 3 would pass through and the outside air. To this partition wall 243, a plural number of exhaust holes 244 for discharging the He gas flowing from the line drawing furnace 11 inside and the dusts generated inside the line drawing furnace 11 are formed.

The No. 2 buffer chamber 245 possesses the partition wall 246 for dividing the inside space where the optical fiber 3 would pass through and the outside air. To this partition wall 246, the introduction tube 247 for introducing air or N_2 gas into the No. 2 buffer chamber 245 is formed. Air or N_2 gas is delivered from the gas supply portion 261 to the introduction tube 247 through the gas supply passage 262. And, to the

partition wall 246, the exhaust tube 248 for discharging the supplied air or N_2 gas is also formed.

The No. 1 buffer chamber 242 and the No. 2 buffer chamber 245 are divided by the dividing wall 249. To the dividing wall 249, the optical fiber passing through hole 250 for the optical fiber 3 to pass through is formed. The inside diameter of the optical fiber passing through hole 250 is set to be about 4—5 mm. The optical fiber passing through hole 250 would suppress the invasions of the He gas from the No. 1 buffer chamber 242 to the No. 2 buffer chamber 245 and the invasion of the dusts generated inside the line drawing furnace 11.

And, the buffer chamber 241 (No. 2 buffer chamber 245) and the protective tube 21 are divided by the dividing wall 251. To the dividing wall 251, the optical fiber passing through hole 254, for the optical fiber 3 to pass through, is formed. The optical fiber passing through hole 254 is set to be about 4—5 mm in inside diameter. Most of the gas introduced into the No. 2 buffer chamber 245 would be discharged from the exhaust tube 144. Further, the introduction of N_2 gas, etc. are to prevent the He gas, etc. to enter the protective tube 21; it is not intended to fill up the protective tube 21 by N_2 gas, etc.

When the amount of the air or N_2 gas introduced from the gas supply portion 261 into the No. 2 buffer chamber 245 through the gas supply passage 262 and the introduction tube 247 is too much, the air or N_2 gas introduced into the No. 2 buffer chamber 245 would flow into the protective tube 21 through the optical fiber passing hole 254 of the dividing wall 251. By this, in the protective tube 21, the downward (line drawing direction) flow would occur. When the amount of the air or N_2 gas introduced

from the gas supply portion 261 into the No. 2 buffer chamber 245 through the gas supply passage 262 and the introduction tube 247 is too little, the upward (opposite to the line drawing direction) flow would occur in the protective tube 21.

Next, based on Fig 4, the experimental results performed by using the above described line drawing equipment 1 and 201 are illustrated. The common conditions in these experiments are as follows. The optical fiber preform 2 used for line drawing was that the core portion was composed of pure quartz, the clad portion was composed of fluorine doped glass, and the outside diameter was 70 mm; from this optical fiber preform 2, the optical fiber 3 of outside diameter 125 um was line drawn. The temperature of the line drawing furnace was set to 2000°C at the surface temperature of the furnace core tube inside circumference face (the face opposing the surface of the optical fiber preform 2 or the optical fiber 3).

Implementation Example 1—Implementation Example 3 are implementation examples by the manufacturing method of the optical fiber related to the above described No. 1 Implementation Mode—No. 3 Implementation Mode; Comparison Example 1—Comparison Example 4 are comparison examples performed to compare the implementation examples based on the manufacturing method of the optical fiber related to the above described No. 1 Implementation Mode—No. 3 Implementation Mode.

(Implementation Example 1)

Using the line drawing equipment 1 in the No. 1 Implementation Mode, the optical fiber 3 was line drawn at line drawing speed 400 m/min. The inside circumference diameter of the protective tube 21 was set to be 30 mm and the total length was set to be 1000 mm. The length L1 of the buffer chamber 41 in the line drawing

direction of the optical fiber 3 was set to be 50 mm. Further, the temperature of the optical fiber immediately before entering the buffer chamber 41 (entering line temperature) was presumed to be 1800°C at the surface temperature of the optical fiber. The temperature of the optical fiber immediately before entering the protective tube 21 (entering line temperature) was presumed to be 1650°C at the surface temperature of the optical fiber. In the protective tube 21, among the line drawn optical fiber 3, the portion whose temperature was becoming 1650—1000°C would be cooled in the entire length of the protective tube 21 of 1000 mm at average cooling speed of 4300°C/second. And the He gas concentration inside the furnace core tube extension portion 16 was 100%; this was lowered gradually in the buffer chamber 41 (He gas concentration 0—100%) and became 0% inside the protective tube 21 (air concentration 100% here).

The transmission loss (transmission loss against wavelength 1.55 um) of the line drawn optical fiber was measured and found to be 0.170 dB/km; the Rayleigh scattering coefficient obtained from the measured data of the wavelength characteristics of this transmission loss was 0.85 dB um^4/km. The outside diameter of the line drawn optical fiber was measured and found to be 125 $\pm$ 0.15 um; the fluctuation of the optical fiber diameter was $\pm$ 0.15 um. And the "bending abnormality" was 0%. The "bending abnormality" was obtained as follows: the curvature radii at different locations of the optical fiber are measured and the portions which are above a specified curvature radius are counted as bad (in the present implementation example: above 4.2 m) and ratio of the number of the locations detected as bad against the measured location number n (in the present implementation example: n = 10) is expressed in percentage.

(Implementation Example 2)

Using the line drawing equipment 101 in the No. 2 Implementation Mode, the optical fiber 3 was line drawn at line drawing speed 400 m/min. The inside circumference diameter of the protective tube 21 was set to be 30 mm and the total length was set to be 1000 mm. The length L3 of the buffer chamber 141 in the line drawing direction of the optical fiber 3 was set to be 50 mm; and the length L2 of the furnace core extension portion 16 in the line drawing direction of the optical fiber 3 was set to be 50 mm.. Further, the temperature of the optical fiber immediately before entering the buffer chamber 141 (entering line temperature) was presumed to be 1800°C at the surface temperature of the optical fiber. The temperature of the optical fiber immediately before entering the protective tube 21 (entering line temperature) was presumed to be 1720°C at the surface temperature of the optical fiber. In the protective tube 21, among the line drawn optical fiber 3, the portion whose temperature was becoming 1720—1050°C would be cooled in the entire length of the protective tube 21 of 1000 m at average cooling speed of 4460°C/second. And, the He gas concentration inside the furnace core tube extension portion 16 was 100%; the He gas concentration inside the protective tube 21 was 0% (air concentration 100% here).

The transmission loss (transmission loss against wavelength 1.55 um) of the line drawn optical fiber was measured and found to be 0.170 dB/km; the Rayleigh scattering coefficient obtained from the measured data of the wavelength characteristics of this transmission loss was 0.85 dB um^4/km. The outside diameter of the line drawn optical fiber was measured and found to be 125 $\pm$ 0.15 um; the fluctuation of the optical fiber diameter was $\pm$ 0.15 um. And the "bending abnormality" was 0%.

(Implementation Example 3)

Using the line drawing equipment 201 in the No. 3 Implementation Mode, the optical fiber 3 was line drawn at line drawing speed 400 m/min. The inside circumference diameter of the protective tube 21 was set to be 30 mm and the total length was set to be 1000 mm. The length L4 of the buffer chamber 241 in the line drawing direction of the optical fiber 3 was set to be 50 mm; and the length L2 of the furnace core extension portion 16 in the line drawing direction of the optical fiber 3 was set to be 50 mm. Using the gas supply portion 261 and the supply passage 262, N_2 gas at 3 litter/min was supplied from the introduction tube 247 into the No. 2 buffer chamber 245. Further, the temperature of the optical fiber immediately before entering the buffer chamber 241 (entering line temperature) was presumed to be 1800°C at the surface temperature of the optical fiber. The temperature of the optical fiber immediately before entering the protective tube 21 (entering line temperature) was presumed to be 1720°C at the surface temperature of the optical fiber. In the protective tube 21, among the line drawn optical fiber 3, the portion whose temperature was becoming 1720—1050°C would be cooled in the entire length of the protective tube 21 of 1000 m at average cooling speed of 4460°C/second. And the He gas concentration inside the furnace core tube extension portion 16 and was 100%; the He gas concentration inside the protective tube 21 was 0% (air concentration 100% here).

The transmission loss (transmission loss against wavelength 1.55 um) of the line drawn optical fiber was measured and found to be 0.170 dB/km; the Rayleigh scattering coefficient obtained from the measured data of the wavelength characteristics of this transmission loss was 0.85 dB um^4/km. The outside diameter of the line drawn optical

fiber was measured and found to be 125 $\pm$ 0.15 um; the fluctuation of the optical fiber diameter was $\pm$ 0.15 um. And the "bending abnormality" was 0%.

(Comparison Example 1)

As shown in Fig 5, by using the construction in that the buffer chamber 41, 141, 241 were removed, the line drawing of optical fiber was carried out. The spacing L5 between the furnace core extension portion 16 and the protective tube 21 was set to be 50 mm; and the length L2 of the furnace core extension portion 16 in the line drawing direction of the optical fiber 3 was set to be 50 mm. Other conditions were identical to Implementation Example 1.

The transmission loss (transmission loss against wavelength 1.55 um) of the line drawn optical fiber was measured and found to be 0.172 dB/km; the Rayleigh scattering coefficient obtained from the measured data of the wavelength characteristics of this transmission loss was 0.86 dB um^4/km. The outside diameter of the line drawn optical fiber was measured and found to be 125 $\pm$ 0.4 um; the fluctuation of the optical fiber diameter was $\pm$ 0.4 um. And the "bending abnormality" was 20%.

(Comparison Example 2)

As shown in Fig 6, by using the construction in that the protective tube 21 was removed, the line drawing of optical fiber was carried out. The length L6 of the furnace core extension portion 16 in the line drawing direction of the optical fiber 3 was set to be 0.5 m. Other conditions were identical to Implementation Example 1.

The transmission loss (transmission loss against wavelength 1.55 um) of the line drawn optical fiber was measured and found to be 0.175 dB/km; the Rayleigh scattering coefficient obtained from the measured data of the wavelength characteristics of this

transmission loss was 0.87 dB um^4/km. The outside diameter of the line drawn optical fiber was measured and found to be 125 $\pm$ 0.15 um; the fluctuation of the optical fiber diameter was $\pm$ 0.15 um. And the "bending abnormality" was 0%.

(Comparison Example 3)

By using the construction without the protective tube 21, the line drawing of optical fiber was carried out. The length L2 of the furnace core extension portion 16 in the line drawing direction of the optical fiber 3 was set to be 50 mm. Other conditions were identical to Implementation Example 1.

The transmission loss (transmission loss against wavelength 1.55 um) of the line drawn optical fiber was measured and found to be 0.170 dB/km; the Rayleigh scattering coefficient obtained from the measured data of the wavelength characteristics of this transmission loss was 0.85 dB um^4/km. The outside diameter of the line drawn optical fiber was measured and found to be 125 $\pm$ 1 um; the fluctuation of the optical fiber diameter was $\pm$ 1 um. And the "bending abnormality" was 30%.

(Comparison Example 4)

Among the Implementation Example 1, only the setting related to the line drawing speed was changed to carry out the line drawing of the optical fiber. The line drawing speed was set to be 100 m/minute. Furthermore, the temperature of the optical fiber immediately before entering the buffer chamber 41 (entering line temperature) was presumed to be 1300°C at the surface temperature of the optical fiber. The temperature of the optical fiber immediately before entering the protective tube 21 (entering line temperature) was presumed to be 1000°C at the surface temperature of the optical fiber.

The transmission loss (transmission loss against wavelength 1.55 um) of the line drawn optical fiber was measured and found to be 0.175 dB/km; the Rayleigh scattering coefficient obtained from the measured data of the wavelength characteristics of this transmission loss was 0.87 dB um^4/km. The outside diameter of the line drawn optical fiber was measured and found to be 125 $\pm$ 0.15 um; the fluctuation of the optical fiber diameter was $\pm$ 0.15 um. And the "bending abnormality" was 0%.

As described above, in Implementation Example1—Implementation Example 3, the Rayleigh scattering coefficient was 0.85 dB um^4/km; and the transmission loss against wavelength 1.55 um became 0.170 dB/km. In Comparison Example 2 where the furnace core tube length portion 16 was made longer, the Rayleigh scattering coefficient was 0.87 dB um^4/km; and the transmission loss against wavelength 1.55 um became 0.175 dB/km. By comparison, the Rayleigh scattering coefficient was be able to be lowered to yield lower the transmission loss in the implementation examples

And, in Implementation Example 1—Implementation Example 3, the fluctuation of the optical fiber diameter became $\pm$ 0.15 um and the "bending abnormality" was 0%. In Comparison Example 1 where the buffer chambers 41, 141, 241 were removed and under the condition of setting the spacing L5 between the line drawing furnace 11 and the protective tube 21 to be L5, the line drawing was performed: the fluctuation of the optical fiber diameter became $\pm$ 0.4 um and the "bending abnormality" was 20%. And, in Comparison Example 3, the protective tube 21 was removed: here the fluctuation of the optical fiber diameter became $\pm$ 1 um and the "bending abnormality" was 30%. Clearly, in Implementation Example 1—Implementation Example 3, the occurrence of the

fluctuation of the optical fiber diameter and the degradation of bending of the optical fiber were suppressed.

And, in Comparison Example 4, the Rayleigh scattering coefficient was 0.85 dB um^4/km; and the transmission loss against wavelength 1.55 um became 0.175 dB/km; the transmission loss became higher than that of Implementation Example 1 where the line drawing speed was set to 400 m/min. This is thought that in Comparison Example 4, the optical fiber 3 is rapidly cooled by the He gas up to the exiting of the furnace core tube extension portion 16 due to the slower line drawing speed at 100 m/min.

As above, it is clear from the above described experimental results that in the manufacturing method of the optical fiber related to the present invention, the protective tube 21 is provided with a specified spacing against the furnace core tube extension portion 16; and furthermore, the space between this protective tube 21 and the line drawing furnace 11 is set to be a gas mixture existing layer (buffer chambers 41, 141, 241) where He gas and air are mixed. Because of this, inside the line drawing furnace 11 is maintained to an atmosphere composed of He gas; inside of the buffer chamber 41, 141, 241 is set to be a gas mixture existing layer of He gas and air. And, in the protective tube 12, an atmosphere composed of air is maintained. Therefore, the cooling speed of the optical fiber inside the protective tube 21 can be made slower. Especially, since the line entering temperature into the gas mixture existing layer of the line-drawn optical fiber 3 is set to be in the range of 1400—1800°C, the cooling speed of a specific section among the portion where the optical fiber 3 temperature is within 1200—1700°C would become slower. As a result, structural relaxation of the optical fiber 3 would proceed within a short time and the degree of disorder of the atomic arrangement would be

lowered; thus, in an extremely short time from the heating-drawing to the resin coating, the Rayleigh scattering intensity is reduced so that the manufacturing of the optical fiber 3 lowered in transmission loss can be achieved. Moreover, for lowering the Rayleigh scattering intensity further to lower the transmission loss, it is preferable to set the line entering temperature of the optical fiber 3 into the gas mixture existing layer to the range from 1600 to 1800°C.

And, since the gas mixture existing layer is present between the protective tube 21 and the line drawing furnace 11, the invasion of dusts generated inside the line drawing furnace 11 into the protective tube 21 can be suppressed. Furthermore, by the presence of the gas mixture existing layer, the influence of the outside air flow disturbance to the space between the line drawing furnace 11 and the protective tube 21 would become less; thus, the occurrence of the optical fiber diameter fluctuation or the degradation of the bending of the optical fiber 3 can be suppressed.

And, since buffer chambers 41, 141, 242 possess partition walls 43, 46, 142, 243, 246, the influence of the disturbance of the outside air flow can be securely suppressed; thus, the occurrence of optical fiber diameter fluctuation or the degradation of the bending of the optical fiber 3 can be further suppressed.

And since the He gas and the dusts generated inside the line drawing furnace 11 are discharged to the outside from the exhaust hole 44 formed to the partition wall 43, the exhaust tube 47 formed to the partition wall 46, the exhaust tube 22 formed to the protective tube 21, the exhaust tube 144 formed to the partition wall 142 or the exhaust hole 244 formed to the partition wall 243, the atmosphere composed of the He gas inside

the line drawing furnace 11 and the atmosphere composed of the air inside the protective tube can be effectively and securely changed.

And, to the partition wall 142 for dividing the buffer chamber 141 and the outside, the introduction tube 143 for introducing the N_2 gas delivered through the N_2 gas supply passage 152 is formed and by introducing N_2 gas from this introduction tube 143 into the buffer chamber 141, the He gas flowing from the line drawing furnace 11 inside and the dusts generated inside the line drawing furnace 11 would be actively discharged from the exhaust tube 144 formed to the partition wall 142. By this, the invasion of the dusts generated inside the line drawing furnace 11 into the protective tube 21 can be further suppressed.

And, to the partition wall 246 for dividing the No. 2 buffer chamber 245 and the outside, the introduction tube 247 for introducing the air or N_2 gas delivered from the gas supply portion 261 through the gas supply passage 262 is formed; and by introducing air or N_2 gas from this introduction tube 247 into the No. 2 buffer chamber 245, the invasion of the dusts generated inside the line drawing furnace 11 into the protective tube 21 can be further suppressed.

In the No. 1 Implementation Mode and the No. 3 Implementation Mode, the buffer chambers 41, 241 are constructed by the No. 1 buffer chambers 42, 242 and the No. 2 buffer chambers 45, 245. However, it is not limited to this; it can be constructed by 3 or more than 3 buffer chambers.

And, in the No. 1 Implementation Mode 1--the No. 3 Implementation Mode, as long as there is a gas mixture layer present between the furnace core tube extension portion 16 and the protective tube 21, the provision of the buffer chamber itself (41, 141,

241) is not absolutely required. In this case, the line drawing furnace 11 (furnace core tube extension portion 16) and the protective tube 21 are to be set up closer. For example, by making the space L1 between the line drawing furnace 11 (furnace core tube extension portion 16) and the protective tube 21 to be about 10 mm, the space between the line drawing furnace 11 (furnace core tube extension portion 16) and the protective tube 21 would become the gas mixture existing layer in that the He gas (to become the atmospheric gas of the line drawing furnace (furnace core tube 13)) and the specified gas (air or N_2, etc. to become the atmospheric gas inside the protective tube 21) are mixed; this would become a condition which is essentially divided (isolated) from the outside to achieve the function-effect similar to that where the buffer chambers 41, 141, 241 are provided. However, due to the fact that the disturbance of the outside air flow can be more securely prevented by making the pressure inside the buffer chambers 41, 141, 241 higher than the outside atmospheric pressure; therefore, it is preferable to adopt the construction of providing the buffer chambers 41, 141, 241.

And, in addition to the optical fiber preform (constructed by the core portion composed of pure quartz and the clad portion composed of fluorine doped glass) used in the above described implementation examples, the present invention can be applied to, for instance, a Ge doped optical fiber preform (Ge doped to the core portion).

Industrial Utilization Possibilities

The manufacturing equipment and the manufacturing method of the present invention can be utilized for the line drawing equipment for line drawing of optical fiber from an optical fiber preform.

SCOPE OF THE CLAIM

1. A manufacturing method of optical fiber having the following characteristics: It is a manufacturing method of optical fiber in that an optical fiber preform is heated-line drawn. In this, a line drawing furnace for heating-line drawing the optical fiber preform under an atmosphere composed of He gas and a protective tube which is arranged with a specified spacing against the line drawing furnace and the atmosphere inside the protective tube is composed of a specific gas possessing a thermal conductivity which is lower than that of He gas are used.

The aforementioned space between the aforementioned line drawing furnace and the aforementioned protective tube is set to be a gas mixture existing layer where He gas and the specific gas are mixed.

The line entering temperature of the aforementioned optical fiber line-drawn into the aforementioned gas mixture existing layer is set to be 1400—1800°C and meanwhile, the aforementioned optical fiber line drawn from the aforementioned line drawing furnace is delivered into the aforementioned protective tube through the gas mixture existing layer.

2. In the manufacturing method of optical fiber described in Claim Item 1, characteristically, a partition wall for dividing the aforementioned gas mixture existing layer and the outside air is provided, and

to the aforementioned partition wall, a gas exhaust portion for exhausting at least the aforementioned He gas is formed, and

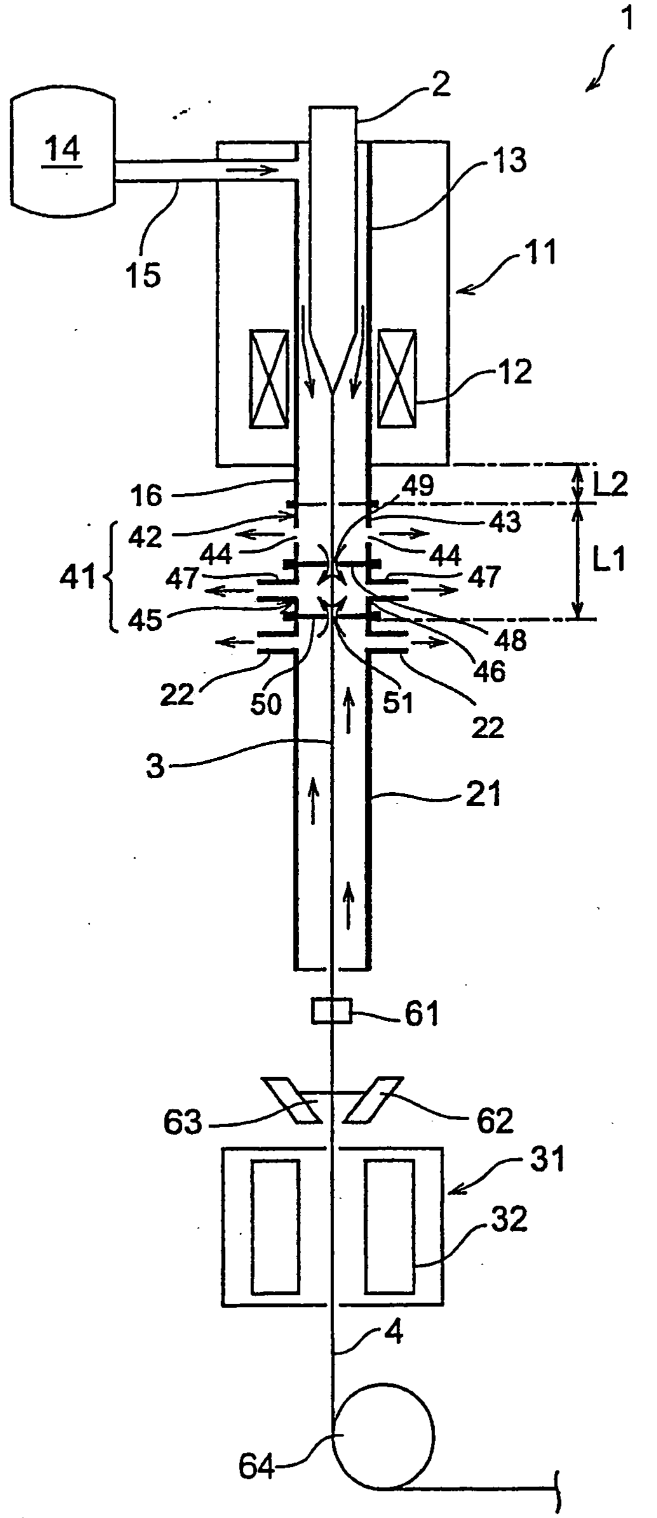
from the aforementioned gas exhaust portion, at least the aforementioned He gas is discharged to the outside.

3. In the manufacturing method of optical fiber described in Claim Item 2, characteristically, to the aforementioned partition wall, a gas introduction portion for introducing the aforementioned specified gas is formed, and

from the aforementioned gas introduction portion, at least the aforementioned specified gas is introduced into the aforementioned partition wall.

Fig 1

図1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2
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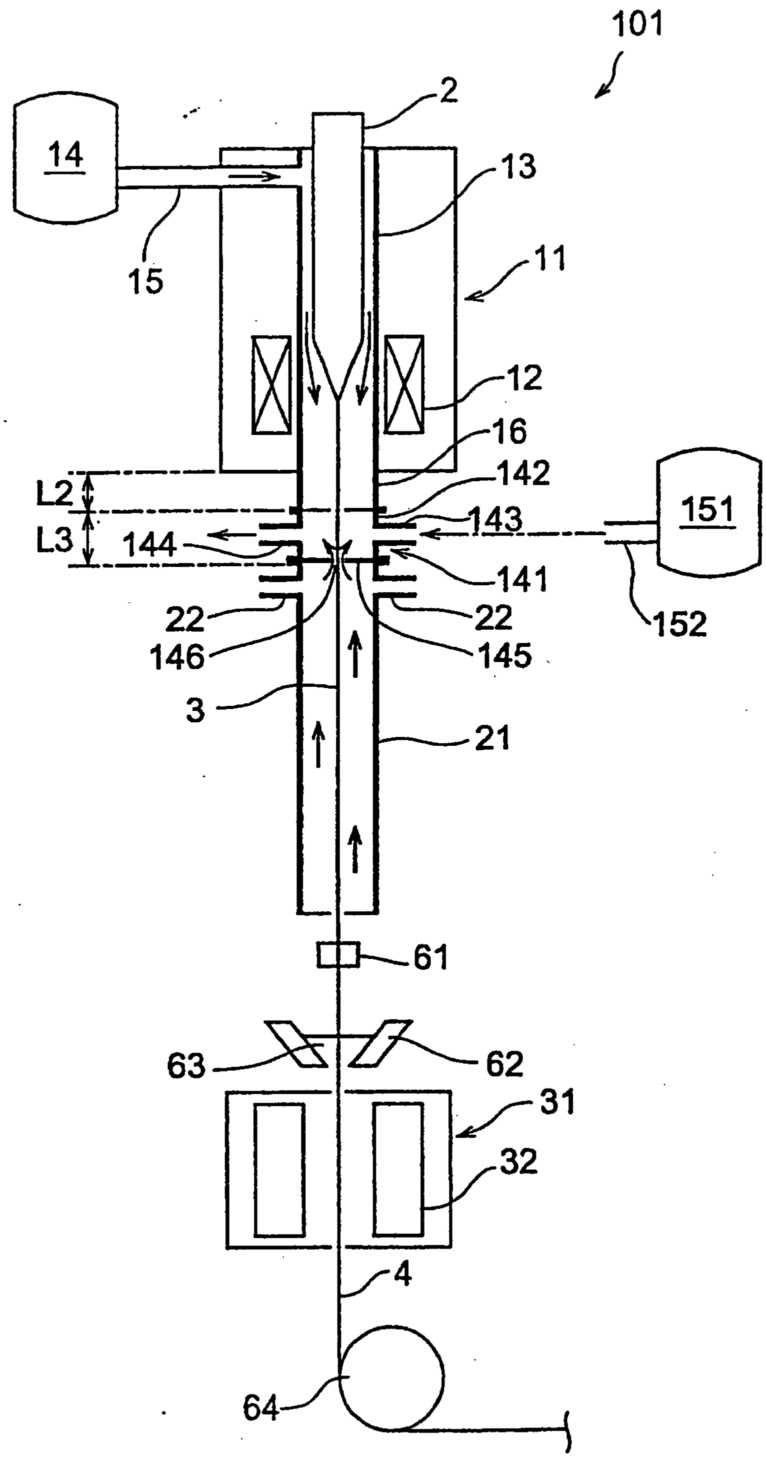
13
15
11
12
16
49
L2
42
43
44
44
L1
41
47
47
45
48
46
22
50
51
22
3
21
61
63
62
31
32
4
64

Fig 2

図2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13
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11
12
16
142
L2
151
143
L3
144
141
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32
4
64

Fig 3

図3

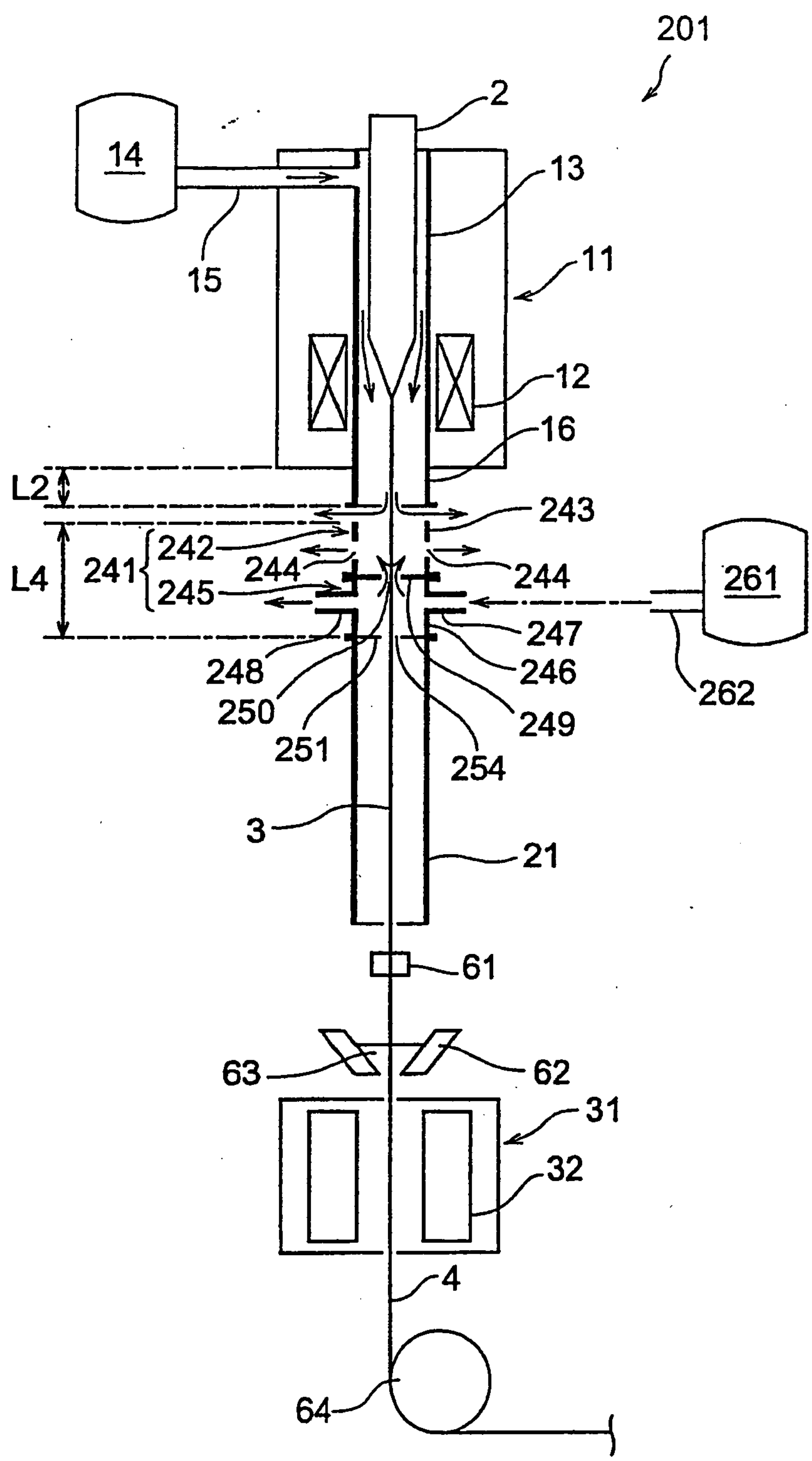

201
2
14
13
15
11
12
16
L2
243
L4
241
242
244
244
245
261
247
248
246
262
250
249
251
254
3
21
61
63
62
31
32
4
64

Fig 4

	Line drawing speed (m/min)	Entering line temp. into buffer chamber (℃)	Fluctuation of optical fiber diameter (μm)	Bending abnormality (%)	Transmission loss (dB/km)	Rayleigh scattering coefficient (dBμm⁴/km)
Implementation Example 1	400	1800	±0.15	0	0.170	0.85
" " 2	400	1800	±0.15	0	0.170	0.85
" " 3	400	1800	±0.15	0	0.170	0.85
Comparison Example 1	400	—	±0.4	20	0.172	0.86
" " 2	400	—	±0.15	0	0.175	0.87
" " 3	400	—	±0.1	30	0.170	0.85
" " 4	100	1300	±0.15	0	0.175	0.87

Fig 5

図5

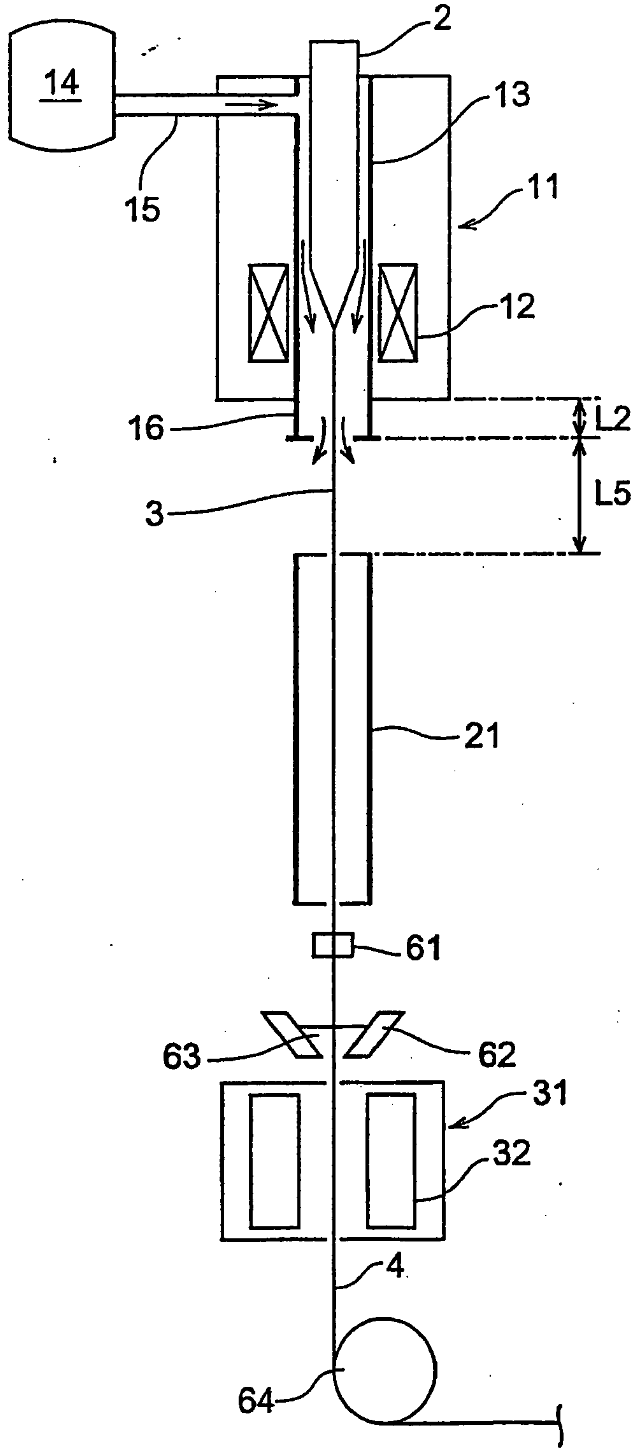
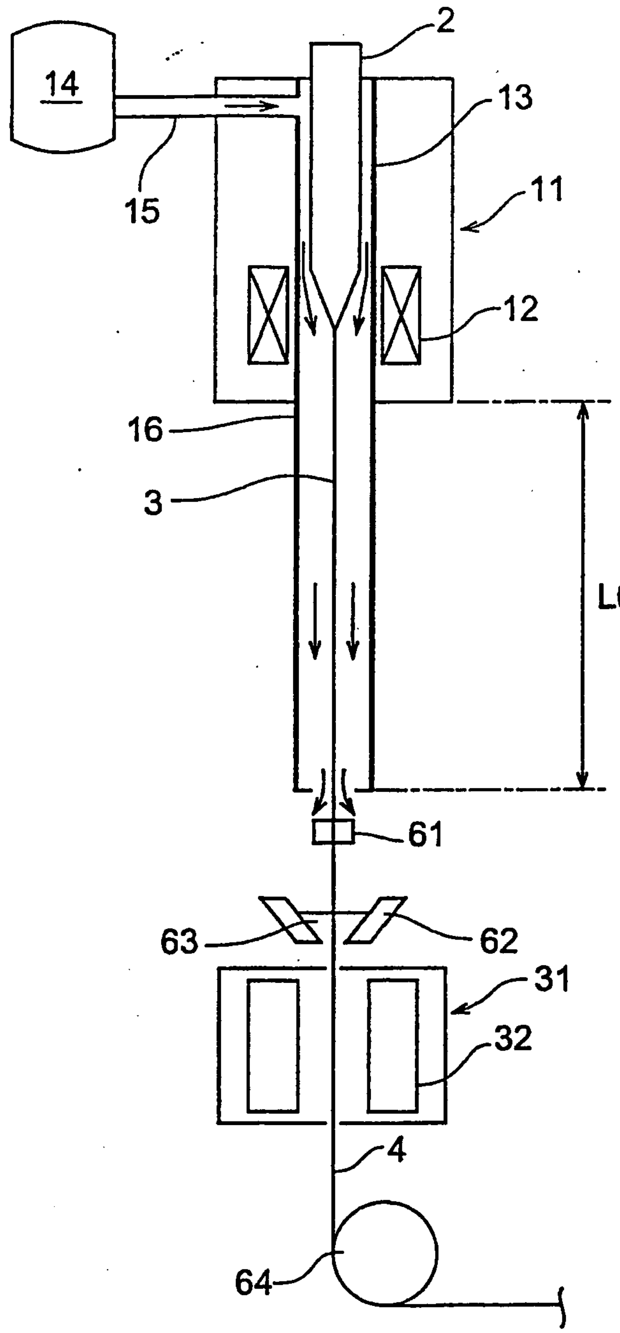


Fig 6

図6



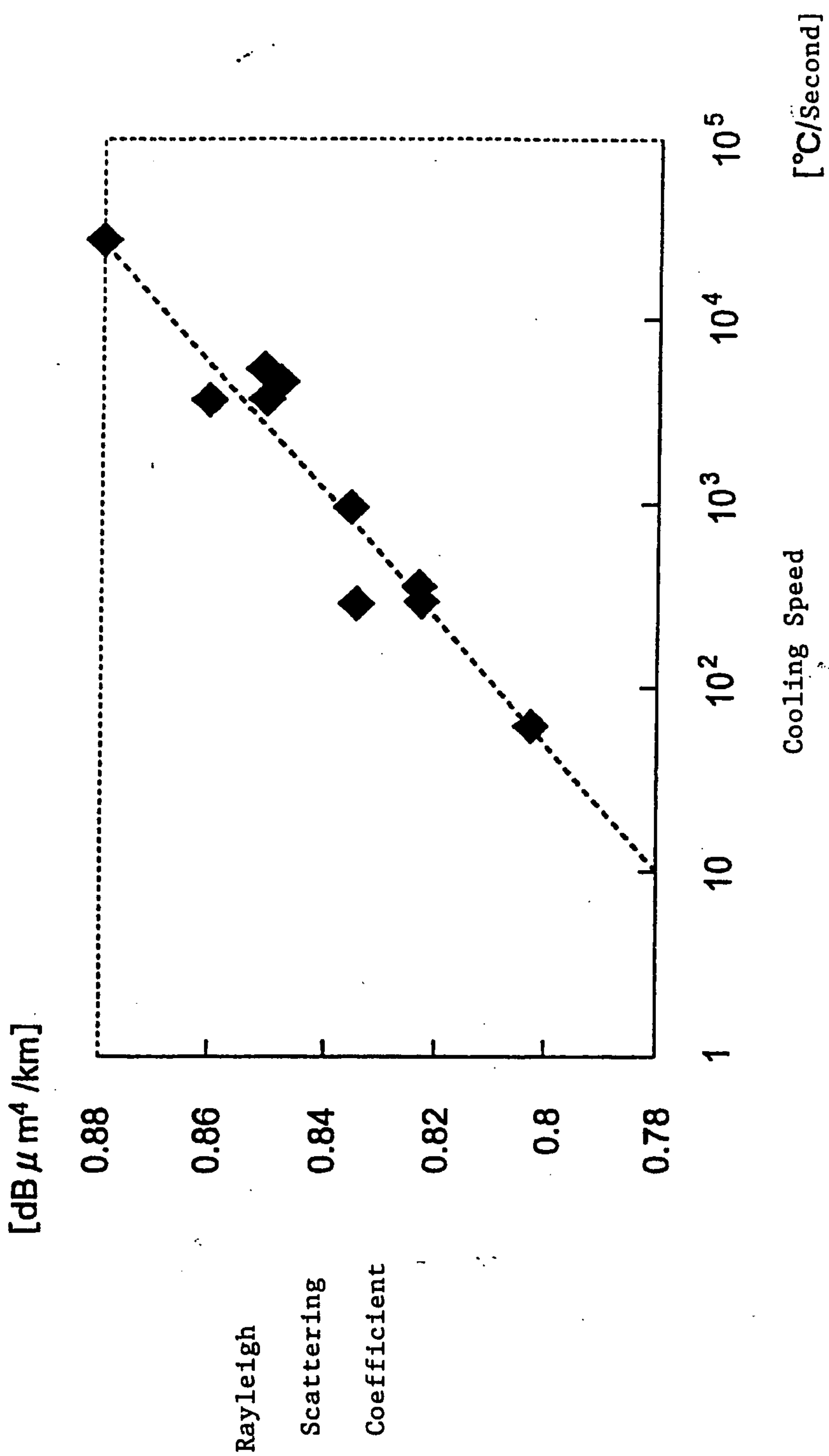

[dB μ m⁴ /km]
0.88
0.86
0.84
0.82
0.8
0.78
1
10
10²
10³
10⁴
10⁵
Cooling Speed
[°C/Second]
Rayleigh Scattering Coefficient

Fig 7

図7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/07053

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl^7 C03B37/027, G02B6/00, 356

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl^7 C03B37/027, G02B6/00, 356

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-2000
Kokai Jitsyo Shinan Koho	1971-2000	Jitsuyo Shinan Toroku Koho	1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI/L(Rayleigh), ECLA(C03B37/027B,C03B37/029)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 11-116264, A (Hitachi Cable, Ltd.), 27 April, 1999 (27.04.99), Par. Nos. [0014]-[0020]; drawings (Family: none)	1-3
A	JP, 1-275443, A (Sumitomo Electric Industries, Ltd.), 06 November, 1989 (06.11.89), Claims, page 4, upper right column; drawings (Family: none)	1-3
A	US, 5320658, A (Sumitomo Electric Industries, Ltd.), 14 June, 1994 (14.06.94), Claims, page 4, column 3, lines 49-53; column 4, lines 6-8; drawings & JP, 4-056931, A, Claims; page 3, upper right column; page 3, lower left column; drawings & EP, 464613, A1	1-3
A	JP, 6-271330, A (Sumitomo Electric Industries, Ltd.), 27 September, 1994 (27.09.94), Par. Nos. [0009],[0014]; drawings (Family: none)	1-3

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search 21 December, 2000 (21.12.00)	Date of mailing of the international search report 16 January, 2001 (16.01.01)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/07053

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 60-046954, A (Nippon Telegr. & Teleph. Corp. <NTT>), 14 March, 1985 (14.03.85), Claims; page 2, lower left column; drawings (Family: none)	1-3
A	JP, 62-246837, A (Sumitomo Electric Industries, Ltd.), 28 October, 1987 (28.10.87), Claims; page 3, upper right column; page 3, lower left column; drawings (Family: none)	1-3
A	JP, 5-105472, A (The Furukawa Electric Co., Ltd.), 24 April, 1993 (24.04.93), Par. Nos. [0017],[0021]; drawings (Family: none)	1-3
EX	JP, 2000-335935, A (Sumitomo Electric Industries, Ltd.), 05 December, 2000 (05.12.00), Claims; drawings (Family: none)	1-3
EX	JP, 2000-335934, A (Sumitomo Electric Industries, Ltd.), 05 December, 2000 (05.12.00), Claims; drawings (Family: none)	1-3
EX	JP, 2000-335933, A (Sumitomo Electric Industries, Ltd.), 05 December, 2000 (05.12.00), Claims; drawings (Family: none)	1-3
EY	JP, 2000-128566, A (Hitachi Cable, Ltd.), 09 May, 2000 (09.05.00), Claims; Par. No. [0017]; drawings (Family: none)	1-3